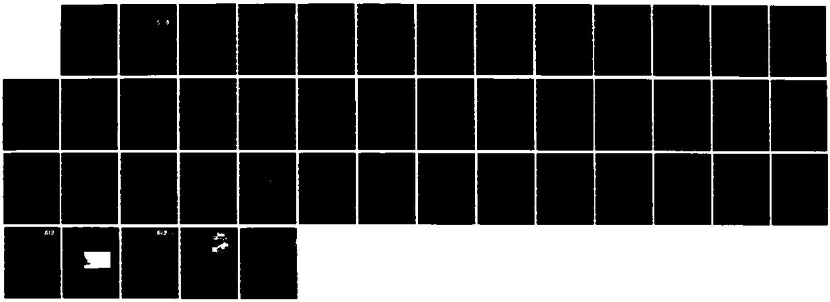
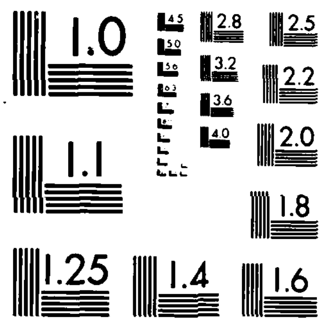
AD-A173 831 DIGISONDE 256 RF POWER TESTS AT WALLOPS ISLAND(U) 1/1
LOWELL UNIV MA CENTER FOR ATMOSPHERIC RESEARCH
D M HAINES AUG 86 SCIENTIFIC-5 AFGL-TR-86-0185
UNCLASSIFIED F19628-83-C-0092 F/G 4/1 NL





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AFGL-TR-86-0185

(12)

DIGISONDE 256 RF POWER TESTS AT WALLOPS ISLAND
TEST EVALUATION REPORT

AD-A173 831

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Scientific Report No. 5

AUGUST 1986

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AIR FORCE GEOPHYSICS LABORATORY
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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

AD-A173831

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; Distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFGL-TR-86-0185
6a. NAME OF PERFORMING ORGANIZATION University of Lowell Ctr for Atmospheric Research 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Air Force Geophysics Laboratory
6c. ADDRESS (City, State and ZIP Code) 450 Aiken Street Lowell, MA 01854	7b. ADDRESS (City, State and ZIP Code) Hanscom AFB Massachusetts 01731
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F19628-83-C-0092
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO.: 62101F PROJECT NO.: 4643 TASK NO.: 08 WORK UNIT NO.: AD
11. TITLE (Include Security Classification) Digisonde 256 RF Power Tests at Wallops Island - Test and Evaluation Report	
12. PERSONAL AUTHOR(S) D. Mark Haines	
13a. TYPE OF REPORT Scientific Report #5 13b. TIME COVERED FROM ______ TO ______	14. DATE OF REPORT (Yr., Mo., Day) 1986 August 15. PAGE COUNT 46
16. SUPPLEMENTARY NOTATION	
17. COSATI CODES FIELD / GROUP / SUB. GR.	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Automatic scaling Ionogram Ionospheric sounder Real time profiles

19. ABSTRACT (Continue on reverse if necessary and identify by block number) A Digisonde 256 ionosonde system was operated at Wallops Island, VA for a period of two weeks at transmitter power levels ranging from 30 Watts to 7 kWatts. This data and the analysis contained in the report should determine for mid-latitude users, the minimum power required to make acceptable measurements. This data was intended to answer questions concerning the co-site compatibility of the Digisonde 256 to allow for installation engineering and site considerations which will minimize potential problems.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL J. Waaramaa	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL AFGL/LIS

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

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ACKNOWLEDGEMENT

The author would like to thank Dr. B. W. Reinisch for his guidance in preparing these experiments and Messrs. D. F. Kitrosser, E. Li, T. Bullet and Dr. K. Bibl in readying the Digisonde 256 System, and Mr. J. Waaramaa for his advice and help during the tests at Wallops Island.

1.0 INTRODUCTION

1.1 Objective

This experiment was performed by the Air Force Geophysics Laboratory, AFGL/LIS, Hanscom AFB, Massachusetts and the University of Lowell Center for Atmospheric Research under Contract No. F19628-83-C-0092 with AFGL/LIS to determine the minimum Digisonde 256 transmitter power required for the acquisition of acceptable automatically processed ionogram data at a mid-latitude site. The experiment was conducted in accordance with the AFGL and ULCAR Test Plans (see Section 4.0). This data, in conjunction with antenna pattern measurements and distortion measurements made by SRI International concurrently with the low power tests, will be used to support site selection and antenna orientation considerations at future Digisonde 256 operating sites.

1.2 Approach

A Digisonde 256 produced by the University of Lowell's Center for Atmospheric Research (Bibl and Reinisch, 1978) with a 7-element array of magnetic loop receiving antennas was deployed at the NASA Wallops Flight Facility, Wallops Island, Virginia on 16 June 1986. A programmable attenuator was inserted between the Digisonde 256 Processor's RF output and the 10 kW final amplifier to provide control of the transmitter output power. Four power levels were used with nominal output power of 7 kW, 1 kW, 170 W and 30 W (actual measured outputs versus frequency are plotted in Figure 1). These levels were achieved using 0 dB, 22 dB, 28 dB and 34 dB of in-line attenuation under automatic control of the Processor's input computer. The transmitter could be operated into either of two antennas, a TCI (Technology for Communications International) 613 or TCI 613T antenna, for which the data sheets are included in Appendix A. These were

also selected under automatic control of the Processor's input computer via a coaxial relay. Therefore, a total of eight operational configurations were employed, four power levels into each of two antennas.

The eight configurations were each operated once every 30 minutes for 24 hours per day (except when the system was needed to support antenna pattern measurements or transmit signal distortion measurements) from 20 June 1986 to 4 July 1986.

The hourly operating schedule was as follows:

XX:00	7 kW	on TCI 613
XX:02	1 kW	on TCI 613
XX:04	170 W	on TCI 613
XX:06	30 W	on TCI 613
XX:10	7 kW	on TCI 613T
XX:12	1 kW	on TCI 613T
XX:14	170 W	on TCI 613T
XX:16	30 W	on TCI 613T
XX:30	7 kW	on TCI 613
XX:32	1 kW	on TCI 613
XX:34	170 W	on TCI 613
XX:36	30 W	on TCI 613
XX:40	7 kW	on TCI 613T
XX:42	1 kW	on TCI 613T
XX:44	170 W	on TCI 613T
XX:46	30 W	on TCI 613T

The scanning ionogram program was set up to transmit 128 phase coded pulses (inter-pulse coding) and to alternate the polarization of the receiver antennas between X polarization (right-hand circular) and 0 polarization (left-hand circular). The pulse repetition rate was 100 pps which resulted in a total coherent integration time of 1.28 seconds. The 133 μs pulse width was used. With pre-transmission listening (to select clear frequencies) and another overhead period for AGC set-up, these parameters allowed a new

frequency to be sounded each 1.5 seconds. A full description of the optional set-up parameters is available in reference 3 (Bibl, Reinisch, Kitrosser, 1981). We selected 100 kHz frequency steps and a scanning range of 1 MHz to 8 MHz which resulted in 70 frequencies or 105 seconds per ionogram. The integration time for the 30 W ionogram was doubled since we doubted that a useful measurement could be made at that power level with only a 1.28 second integration time. Therefore, by integrating 128 pulses and leaving all other parameters the same a 210 second ionogram was produced for the lowest power measurement.

The Digisonde 256 includes a digital tape drive and a hard copy printer which were augmented for this test by a second printer and second tape drive. This enabled the recording of both the raw ionogram data and also the processed output of the ARTIST (Automatic Real-Time Ionogram Scaler with True-height analysis) program running on the IBM/AT computer, which is also part of the Digisonde 256 system. The data analysis which follows is essentially a report of the ARTIST's performance (Reinisch and Huang, 1983) on the degraded data resulting from the various attenuated transmitter power levels.

2.0 ANALYSIS

2.1 General

General observation of the raw ionogram output typified by Figure 2 (taken around 1600 UT on Julian Day 176, June 25, 1986) showed an obvious degradation of signal to noise ratio as power was decreased, however, since the ARTIST employs very sophisticated noise elimination algorithms an aesthetically displeasing ionogram may not indicate a poor measurement. A simple noise elimination is applied before printing so the noise level in the figure is not apparent, but the ARTIST works on the preprocessed signal. In fact, under certain conditions the thinner traces (narrower range of altitudes for a given trace), which resulted from a weaker signal, allowed the ARTIST to scale the traces more easily since it did not confuse the range extension (delayed returns from off-vertical or higher altitude irregularities) of one layer with the return from the next higher layer. However, in general, the data does show that the higher output power provides a more accurate detection of traces.

The ARTIST provides both an output of the overhead traces and of scaled ionospheric parameters and, in addition, a reconstruction of the electron density profile versus altitude. The auto-scaled parameters are foE, foEs, foF1, foF2, h'E, h'Es, h'F, h'F2, fminE, fminF and M3000. The electron density profile is stored as a second order modified Chebychev polynomial representation of the E region electron density profile and two 6th order modified Chebychev polynomials representing the F1 and F2 profiles. Due to the volume of data produced (over 5,000 ionograms), we decided to statistically analyze only the foF2 and M3000 parameters for all ionograms. These fully employ both the height finding and the frequency measuring accuracy of the system and are the measurements most critical to the operation of radar and communications systems. Also, these parameters do not involve

layers which disappear diurnally such as the E and F1 layers or those which appear sporadically such as the Es layer.

2.2 Description of Analysis Procedure and Results

The figure of merit used is the difference between the measurement at lower power and the measurement at full power. Realizing that the measurement at full power may have been inaccurately scaled by the ARTIST we manually scaled two days worth of data, Day 172 and Day 173, as an experimental control, and compared the automatically analyzed parameters to those obtained manually.

Figure 2a-2f is an example of a plot of one day's worth of foF2 measurements comparing each power level/antenna combination to the most recent full power measurement (on the same antenna), here referred to as the reference sounding. The full power reference measurement was made less than six minutes prior to the attenuated measurement and on the same antenna, except for Days 171 and 172 for which we have no full power measurements on the 613T. For days 171 and 172, therefore, we used the 12 to 16 minute old full power measurement from the 613 antenna as a reference to evaluate the attenuated measurements on the 613T antenna. The codes marking the actual measured data points on the plots are: R - reference measurement on the 613 antenna (7 kW), T - reference measurement on the 613T antenna (7 kW), H - high power (1 kW) measurement, M - medium power (170 W) and L - low power (30 W). The antenna used for the lower power measurement is shown in the title. The large spikes in the curve have a value of 9.9 MHz and indicate times when no F-trace could be found and, though not aesthetically pleasing, they readily allow the number of "misses" per day to be counted manually. Graphs, like the ones shown in Figures 2a-2f and 3a-3f, were created for all of the days reported on, but are not all included in this report due to the huge volume of paper which would be required to print them. The statistics

of interest in these graphs are derived and reported so interest in these graphs should be minimal. However, if someone has a need to study the plots of these scaled parameters, we could make them available in their entirety.

The "misses" at full power were predominantly due to blanketing sporadic E (Es) which prevents the signal from getting up to the F-region altitudes. This condition occurred almost every morning before sunrise when the F-region was very weak, so even a weak Es was sufficient to block the F-region echoes. High power is useful at this point to get sufficient energy through any "holes" which exist in the Es layer. The next most frequent cause of no F-trace detected was short traces. With the low sunspot activity the foF2's were depressed to 2 MHz at night, therefore, occasionally only two or three frequencies (remember, 100 kHz frequency steps were used) would provide F-region echoes and the ARTIST needs at least four echoes to declare a trace present. In order to avoid interfering with WWV, we blanked out the transmission on 2.5 MHz which exacerbated the problem. The next most likely caus of no F-trace detected was a technical problem such as an overcurrent shutdown which automatically turns off the transmitter for 10 seconds, or a power fault which can have the same effect, but these problems were weeded out in the statistical analysis as will be described shortly.

After reading one day's worth of foF2 values for both the reference and attenuated power levels, the differences were computed by subtracting the reference measurement from the lower power measurement. A full set of these (all powers, both antennas) are presented in Figure 3a-3f, corresponding to the foF2 measurements in Figure 2. With the differences calculated, it is possible to compute several statistics which are printed out in Table 1. First, any data points for which either the reference or the variable power measurement failed to produce a parameter were eliminated. Then, three sets of statistics (the median, mean and standard deviation) were generated as follows:

a. The median of the absolute value of the errors for one day's data was computed for each operating configuration. These are encoded as follows:

Ref - most recent full power measurement for respective antenna

H6 - high power, 1 kW, on the 613 antenna

M6 - medium power, 170 W, on the 613 antenna

L6 - low power, 30 W, on the 613 antenna

HT - high power, 1 kW, on the 613T antenna

MT - medium power, 170 W, on the 613T antenna

LT - low power, 30 W, on the 613T antenna

b. The mean of the absolute value of the errors was computed for each operating configuration, and,

c. The standard deviation (RMS error) of the lower power measurement relative to the reference was computed.

Also very informative was a comparison of values left after weeding out data points which represented a condition of no F-trace found (i.e., *failure to scale any parameter values*). Section d. of Table 1 is a simple percentage of the total number of measurements left after weeding out bad ones (those ionograms which could not be scaled automatically and also those which were scaled incorrectly, as described below) compared to the original number of samples (i.e., percent scaled) for each of the eight configurations. Section e. is the percent of each configuration's measurements which did not scale in both the reference and the attenuated measurement. Here I use the term "coincident percentage not scaled" to indicate that *automatic scaling* of both the lower power and reference ionogram were unsuccessful. I also use the term "non-reciprocal failure" in Section f. to indicate that one configuration failed to provide a scaleable ionogram at the same time that the other scaled successfully. Note the format A/B indicates A could not be scaled while B was scaled successfully.

Each variable power configuration was checked against its most recent full power reference measurement, and the reference measurement was checked against each variable power measurement as a statistical check on non-power related failures. The difference between non-reciprocal failures of the lower power and non-reciprocal failures of the reference power is a very good indication of the percentage of failures attributable to reduced power.

Exactly the same approach was taken to analyze the accuracy of the M3000 factors resulting in a set of M3000 statistics presented in Table 2 in exactly the same format as the foF2 statistics. Also, both sets of statistics were generated, Tables 3 and 4, using the manually scaled data from Days 172 and 173 as the reference. Notice that now the performance of the 7 kW configurations can also be analyzed because these are no longer the reference. The term "man," rather than "ref," is used to refer to the manually scaled parameter which is now the standard for comparison (i.e., reference) for these tables. A "**" is used in Tables 3 and 4 to indicate statistics derived from data which was edited to remove instances where the ARTIST automatically scaled F traces when only multiple hop E traces were visible in the manually scaled ionograms. Although this error is an important performance parameter, it confuses the dependence of sealing accuracy on transmitter power so it is better left out of our final results. This error occurred in about 16% of the ionograms from Day 173 (the highest incidence during the two-week period). This is a problem which is worthy of some further development work, but at the moment we do not have a technique which reliably removes multiple hop E traces prior to F trace detection.

3.0 SUMMARY

3.1 Conclusion

Using the performance of the Digisonde 256, including the ARTIST at a 7 kW transmit power level as a reference, the degradation of data quality as a function of reduced transmit power levels was determined for two antennas, the TCI 613T and TCI 613 models.

The statistics of median error, mean error and standard deviation show an acceptable degradation for the 1 kW transmit power level on the 613T antenna. Surprisingly accurate results were obtained at the 170 W transmit level on the 613 antenna. The 613 antenna consistently resulted in a 4 to 6 dB stronger echo than those obtained using the 613T antenna. This is reflected by similarities between percentage scaled from the M6 and the HT configuration. The M6 configuration has over 6 dB less transmitter power than HT, but results in similar and acceptable performance at the 170 W level. Either configuration maintains a low to mid 90's percentage of being able to automatically scale the ionograms with an occasional slip into the 80's. We consider this acceptable for general purpose data to support propagation predictions or radar frequency management.

3.2 Recommendation

Our recommendation for eliminating potential RFI/EMC problems is to insert a 22 dB attenuator at the input to the final amplifier thus reducing the output power to 1 kW when operating at mid-latitude locations with the 613T antenna. Furthermore, if necessary, the output power could be dropped to about 200 W when operating with the 613 antenna.

Since the ARTIST needs four echoes to scale a trace, it had problems scaling the extremely short F traces found on several nights (a result of the current minimum in solar

activity). Switching from 100 kHz per frequency step to 50 kHz per step during low foF2 conditions would very likely improve the low power performance of the ARTIST under these conditions. This would, however, require a Digisonde 256 software modification.

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5.0 TABLES AND FIGURES

TABLE 1 - FOF2 STATISTICS FOR THE WEEK OF 20 JUN - 29 JUN 1986

JULIAN DAY	172	173	174	175	176	177	178	179	180	ROW AVERAGE
a. MEDIAN ABSOLUTE ERROR BETWEEN ATTENUATED AND REFERENCE POWER MEASUREMENT (IN MHZ)										
REF VS H6	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.11
REF VS M6	0.10	0.10	0.20	0.20	0.10	0.10	----	----	----	0.13
REF VS L6	0.30	0.20	0.20	0.20	0.10	0.10	----	----	----	0.18
REF VS HT	0.20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.12
REF VS MT	0.20	0.10	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.12
REF VS LT	0.30	0.20	0.20	0.10	0.10	0.10	0.20	0.10	0.20	0.17
b. MEAN ABSOLUTE ERROR BETWEEN ATTENUATED AND REFERENCE POWER MEASUREMENT (IN MHZ)										
REF VS H6	0.12	0.23	0.25	0.18	0.13	0.23	0.20	0.33	0.13	0.20
REF VS M6	0.23	0.17	0.26	0.31	0.25	0.24	----	----	----	0.17
REF VS L6	0.30	0.27	0.29	0.35	0.13	0.28	----	----	----	0.30
REF VS HT	0.28	0.19	0.25	0.14	0.13	0.13	0.24	0.37	0.22	0.25
REF VS MT	0.27	0.20	0.20	0.18	0.27	0.16	0.29	0.38	0.32	0.26
REF VS LT	0.37	0.23	0.30	0.13	0.14	0.12	0.26	0.37	0.26	0.26
c. STANDARD DEVIATION BETWEEN ATTENUATED AND REFERENCE POWER MEASUREMENT (IN MHZ)										
REF VS H6	0.18	0.35	0.51	0.31	0.23	0.66	0.36	0.66	0.17	0.39
REF VS M6	0.35	0.25	0.38	0.44	0.36	0.66	----	----	----	0.42
REF VS L6	0.41	0.34	0.40	0.48	0.21	0.66	----	----	----	0.46
REF VS HT	0.39	0.26	0.42	0.20	0.47	0.16	0.46	0.88	0.31	0.43
REF VS MT	0.45	0.28	0.36	0.27	0.21	0.22	0.56	0.64	0.47	0.41
REF VS LT	0.38	0.24	0.42	0.18	0.22	0.13	0.53	0.71	0.34	0.37

"----" INDICATES NO DATA AVAILABLE IN THAT CATAGORY

TABLE 1 - Continued

	172	173	174	175	176	177	178	179	180	ROW AVERAGE
d. PERCENT OF ORIGINAL RAW IONOGRAM RECORDS SCALED AUTOMATICALLY										
R6	95.0	97.9	100.	97.4	100.	100.	100.	97.9	100.	98.4
H6	97.5	95.8	100.	97.4	95.6	100.	100.	95.8	100.	98.0
M6	90.0	89.6	100.	97.4	95.6	100.	----	----	----	94.8
L6	85.0	81.3	97.9	92.3	84.7	100.	----	----	----	89.7
RT	----	95.8	100.	97.4	97.8	100.	96.8	97.9	94.3	97.5
HT	97.5	83.3	97.9	92.3	93.4	96.0	96.8	87.5	91.4	93.4
MT	87.5	83.3	97.9	89.7	89.1	88.0	62.5	75.0	82.8	84.4
LT	90.0	72.9	72.9	76.9	69.5	68.0	59.4	64.6	82.8	74.8
e. COINCIDENT PERCENTAGE OF ORIGINAL RAW DATA RECORDS NOT AUTOMATICALLY SCALED BY THE ARTIST FOR EITHER THE ATTENUATED OR REFERENCE POWER LEVEL										
H6 VS REF	2.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
M6 VS REF	5.0	2.1	0.0	0.0	0.0	0.0	----	----	----	1.7
L6 VS REF	5.0	0.0	0.0	0.0	0.0	0.0	----	----	----	1.4
HT VS REF	0.0	2.1	0.0	2.6	2.2	0.0	3.2	2.1	5.7	1.8
MT VS REF	5.0	2.1	0.0	0.0	2.2	0.0	3.2	2.1	5.7	2.5
LT VS REF	5.0	4.2	0.0	2.6	0.0	0.0	3.2	2.1	5.7	2.7
f. PERCENTAGE OF NON-RECIPROCAL FAILURES TO FIND AN F TRACE (of A/B the A configuration failed when the B configuration did not)										
REF/H6	2.5	0.0	0.0	2.6	0.0	0.0	0.0	2.1		1.0
H6/REF	0.0	2.1	0.0	2.6	4.6	0.0	0.0	4.2		1.5
REF/M6	0.0	0.0	0.0	2.6	0.	0.0	---	---		0.4
M6/REF	5.0	8.3	0.0	2.6	4.6	0.0	---	---		3.6
REF/L6	0.0	2.1	0.0	2.6	0.0	0.0	---	---		0.7
L6/REF	10.0	18.7	2.1	7.7	15.3	0.0	---	---		9.0
REF/HT	5.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0		1.3
HT/REF	2.5	14.6	2.1	5.1	4.4	4.0	0.0	10.4		5.0
REF/MT	0.0	2.1	0.0	2.6	0.0	0.0	0.0	0.0		0.5
MT/REF	7.5	14.6	2.1	10.3	8.7	12.0	34.3	22.9		13.3
REF/LT	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0		0.2
LT/REF	5.0	25.0	27.1	20.5	30.5	32.0	37.4	33.3		23.9

* When a reference on the 613T antenna was not available the ten minute old reference data the measurement on the 613 antenna was used as a reference.

TABLE 2 - M3000 STATISTICS FOR 21 JUN - 29 JUN 1986

JULIAN DATE	172	173	174	175	176	177	178	179	180	ROW AVERAGE
a. MEDIAN ABSOLUTE ERROR BETWEEN ATTENUATED AND REFERENCE POWER MEASUREMENT										
REF VS. H6	0.125	0.180	0.110	0.130	0.105	0.060	0.150	0.200	0.090	0.128
REF VS. M6	0.190	0.190	0.170	0.290	0.150	0.110	----	----	----	0.183
REF VS. L6	0.220	0.180	0.210	0.160	0.110	0.130	----	----	----	0.168
REF VS. HT	0.185	0.160	0.130	0.115	0.140	0.090	0.105	0.220	0.165	0.146
REF VS. MT	0.195	0.130	0.150	0.195	0.150	0.170	0.220	0.245	0.180	0.182
REF VS. LT	0.200	0.170	0.160	0.145	0.110	0.130	0.265	0.330	0.250	0.196
b. MEAN ABSOLUTE ERROR BETWEEN ATTENUATED AND REFERENCE POWER MEASUREMENT										
REF VS H6	0.213	0.378	0.235	0.208	0.243	0.135	0.279	0.397	0.301	0.265
REF VS M6	0.275	0.273	0.274	0.418	0.271	0.214	----	----	----	0.287
REF VS L6	0.314	0.362	0.319	0.339	0.199	0.244	----	----	----	0.296
REF VS HT	0.306	0.354	0.237	0.221	0.198	0.175	0.173	0.405	0.216	0.253
REF VS MT	0.329	0.284	0.276	0.303	0.257	0.205	0.229	0.392	0.266	0.282
REF VS LT	0.331	0.326	0.297	0.250	0.183	0.175	0.271	0.468	0.372	0.297
c. STANDARD DEVIATION BETWEEN ATTENUATED AND REFERENCE POWER MEASUREMENT										
REF VS H6	0.338	0.565	0.394	0.327	0.408	0.214	0.461	0.592	0.529	0.425
REF VS M6	0.414	0.415	0.384	0.614	0.415	0.343	----	----	----	0.431
REF VS L6	0.415	0.538	0.437	0.538	0.310	0.387	----	----	----	0.437
REF VS HT	0.469	0.523	0.356	0.317	0.287	0.306	0.288	0.560	0.309	0.379
REF VS MT	0.465	0.446	0.412	0.469	0.371	0.251	0.285	0.517	0.327	0.394
REF VS LT	0.448	0.488	0.406	0.344	0.266	0.177	0.353	0.601	0.526	0.401

TABLE 2 - Continued

JULIAN DATE	172	173	174	175	176	177	178	179	180	ROW AVERAGE
d. PERCENT OF ORIGINAL RAW IONOGRAM RECORDS SCALED AUTOMATICALLY										
R6	93.2	97.9	100.	97.4	100.	100.	96.9	97.9	100.	98.1
H6	93.2	95.8	100.	97.4	95.6	100.	96.9	95.8	100.	97.2
M6	88.6	89.6	100.	97.4	95.6	100.	----	----	----	95.2
L6	84.1	81.3	97.9	92.3	84.8	100.	----	----	----	90.1
RT	----	95.8	100.	97.4	97.8	100.	100.	97.9	94.3	97.9
HT	95.5	83.3	97.9	92.3	93.4	96.0	100.	87.5	91.4	93.0
MT	86.4	83.3	97.9	89.7	89.1	88.0	78.1	75.0	82.8	85.6
LT	90.1	72.9	72.9	76.9	69.6	68.0	68.8	64.6	82.8	74.1
e. COINCIDENT PERCENTAGE OF ORIGINAL RAW DATA RECORDS NOT AUTOMATICALLY SCALED BY THE ARTIST FOR EITHER ATTENUATED OR REFERENCE POWER LEVEL										
H6 VS REF	4.5	2.2	0.0	0.0	0.0	0.0	3.1	0.0	0.0	1.1
M6 VS REF	6.8	2.2	0.0	0.0	0.0	0.0	----	----	----	1.5
L6 VS REF	6.8	0.0	0.0	0.0	0.0	0.0	----	----	----	1.1
HT VS REF	2.3	2.2	0.0	2.6	2.2	0.0	0.0	2.1	5.7	1.9
MT VS REF	6.8	2.2	0.0	0.0	2.2	0.0	0.0	2.1	5.7	2.1
LT VS REF	4.5	4.2	0.0	2.6	0.0	0.0	0.0	2.1	5.7	2.1
f. PERCENTAGE OF NON-RECIPROCAL FAILURES TO FIND AN M3000 PARAMETER (of A/B configurations a failed while b did not)										
REF/H6	2.3	0.0	0.0	2.6	0.0	0.0	0.0	2.1	0.0	0.8
H6/REF	2.3	2.1	0.0	2.6	4.6	0.0	0.0	4.2	0.0	1.8
REF/M6	0.0	0.0	0.0	2.6	0.	0.0	---	---	---	0.4
M6/REF	4.6	8.3	0.0	2.6	4.6	0.0	---	---	---	3.3
REF/L6	0.0	2.2	0.0	2.6	0.0	0.0	---	---	---	0.8
L6/REF	9.1	18.75	2.1	7.7	15.3	0.0	---	---	---	8.8
REF/HT	4.5*	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
HT/REF	2.2*	14.6	2.1	5.1	4.4	4.0	0.0	10.4	2.9	5.1
REF/MT	0.0*	2.1	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.5
MT/REF	6.8*	14.6	2.1	10.3	8.7	12.0	21.9	22.9	11.5	12.3
REF/LT	2.3*	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.5
LT/REF	5.4*	25.0	27.1	20.5	30.4	32.0	31.2	33.3	11.5	24.0

*When a reference measurement on the 613T antenna was not available the ten minute old reference on the 613 antenna was used.

TABLE 3 - ARTIST VS MANUAL SCALING foF2 STATISTICS - 21 JUN - 22 JUN 1986

JULIAN DAY	172	173
a. MEDIAN ABSOLUTE ERROR BETWEEN MANUAL AND AUTOMATIC SCALING (IN MHZ)		
MAN VS 7KW 613 ANTENNA	0.10	0.10
MAN VS 7KW 613T ANTENNA	-----	0.10
MAN VS H6	0.20	0.10
MAN VS M6	0.20	0.10
MAN VS L6	0.30	0.20
MAN VS HT	0.20	0.10
MAN VS MT	0.30	0.10
MAN VS LT	0.30	0.20
b. MEAN ABSOLUTE ERROR BETWEEN MANUAL AND AUTOMATIC SCALING (IN MHZ)		
MAN VS 7KW 613 ANTENNA	0.285	0.185
MAN VS 7KW 613T ANTENNA	-----	0.131
MAN VS H6	0.205	0.233
MAN VS M6	0.246	0.168
MAN VS L6	0.368	0.273
MAN VS HT	0.320	0.192
MAN VS MT	0.324	0.197
MAN VS LT	0.341	0.233
c. STANDARD DEVIATION BETWEEN MANUAL AND AUTOMATIC SCALING (IN MHZ)		
MAN VS 7kW 613 ANTENNA	0.543	0.279
MAN VS 7kW 613T ANTENNA	-----	0.205
MAN VS H6	0.223	0.347
MAN VS M6	0.262	0.246
MAN VS L6	0.451	0.342
MAN VS HT	0.513	0.243
MAN VS MT	0.338	0.258
MAN VS LT	0.365	0.279

TABLE 3 - Continued

JULIAN DATE	172	173
d. PERCENT OF ORIGINAL RAW IONOGRAM RECORDS WHICH WERE SCALED		
MANUALLY SCALED	93.2*	83.3*
R6	89.3**	83.3**
H6	91.5**	81.3**
M6	84.7**	79.2**
L6	80.2**	77.1**
RT	----	83.3**
HT	91.5**	77.1**
MT	82.4**	81.2**
LT	84.8**	68.7**

e. COINCIDENT PERCENTAGE OF ORIGINAL RAW DATA RECORDS NOT AUTOMATICALLY SCALED FOR EITHER THE ATTENUATED OR REFERENCE POWER LEVELS		
R6 VS MAN	4.5	0.0
RT VS MAN	----	2.1
H6 VS MAN	2.3	2.1
M6 VS MAN	4.5	6.2
L6 VS MAN	4.5	12.5
HT VS MAN	0.0	10.4
MT VS MAN	4.5	14.6
LT VS MAN	4.5	12.5

NON-RECIPROCAL FAILURES TO FIND AN F-TRACE (ie. COMPARED TO THE MANUAL SCALING)		
MAN/R6	2.3	16.7
R6/MAN	0.0	2.1
MAN/RT	---	14.6
RT/MAN	---	0.0
MAN/H6	2.2	14.6
H6/MAN	0.0	2.1
MAN/M6	0.0	10.5
M6/MAN	4.6	4.2
MAN/L6	0.0	4.2
L6/MAN	9.1	6.2
MAN/HT	4.5	6.3
HT/MAN	2.3	6.3
MAN/MT	0.0	2.1
MT/MAN	6.9	2.1
MAN/LT	0.0	4.2
LT/MAN	4.6	14.6

* This is the maximum percentage of the ionograms which could be correctly scaled manually or automatically. It was limited by a blaketing Es layer which blocked F region echos.

** The ARTIST often interpreted the multiple hop Es as an F trace. These errors were independent of transmitter power. Therefore to provide a clearer assessment of low power operation, the data records were edited to indicate that the ARTIST was 'unable to scale' these ionograms.

TABLE 4 - ARTIST VS MANUAL SCALING M3000 STATISTICS - 20-21 JUN 1986

JULIAN DAY	172	173
a. MEDIAN ABSOLUTE ERROR BETWEEN MANUAL AND AUTOMATIC SCALING (IN MHZ)		
MAN VS 7KW 613 ANTENNA	0.075	0.057
MAN VS 7KW 613T ANTENNA	-----	0.058
MAN VS H6	0.092	0.161
MAN VS M6	0.139	0.137
MAN VS L6	0.140	0.180
MAN VS HT	0.220	0.119
MAN VS MT	0.167	0.089
MAN VS LT	0.205	0.182
b. MEAN ABSOLUTE ERROR BETWEEN MANUAL AND AUTOMATIC SCALING (IN MHZ)		
MAN VS 7KW 613 ANTENNA	0.183	0.157
MAN VS 7KW 613T ANTENNA	-----	0.147
MAN VS H6	0.184	0.369
MAN VS M6	0.192	0.224
MAN VS L6	0.235	0.307
MAN VS HT	0.265	0.265
MAN VS MT	0.334	0.304
MAN VS LT	0.356	0.285
c. STANDARD DEVIATION BETWEEN MANUAL AND AUTOMATIC SCALING (IN MHZ)		
MAN VS 7KW 613 ANTENNA	0.311	0.284
MAN VS 7KW 613T ANTENNA	-----	0.254
MAN VS H6	0.292	0.523
MAN VS M6	0.251	0.342
MAN VS L6	0.379	0.409
MAN VS HT	0.388	0.413
MAN VS MT	0.461	0.587
MAN VS LT	0.645	0.397

TABLE 4 - Continued

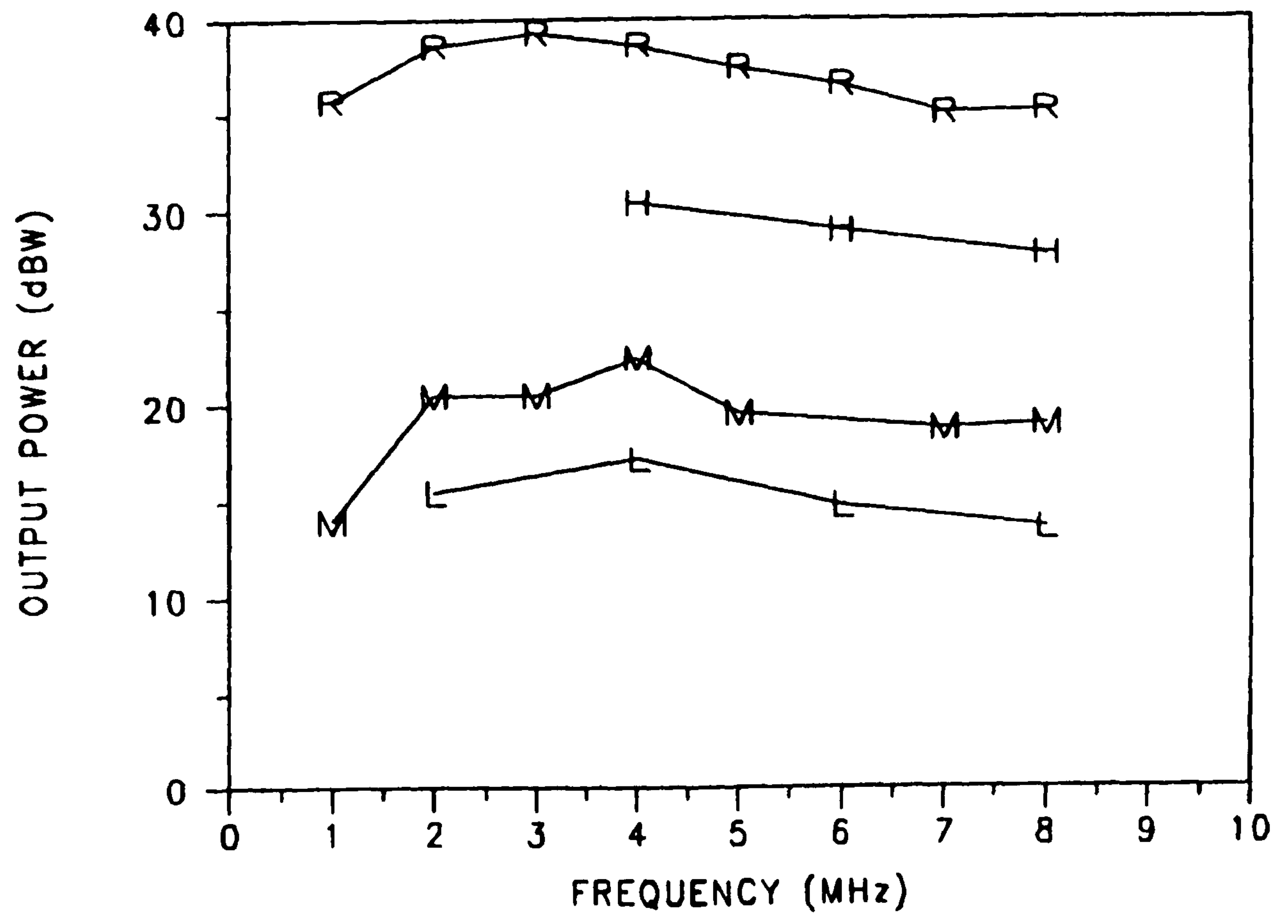
JULIAN DATE	172	173
d. PERCENTAGE OF ORIGINAL RAW IONOGRAM RECORDS SCALED AUTOMATICALLY		
MANUALLY SCALED	87.9*	83.3*
R6	87.2**	81.3**
H6	87.0**	81.3**
M6	82.4**	79.2**
L6	79.9**	77.1**
RT	----	81.3**
HT	89.3**	81.3**
MT	80.4**	77.1**
LT	83.9**	68.8**
e. COINCIDENT PERCENTAGE OF ORIGINAL RAW IONOGRAM RECORDS NOT SCALED FOR EITHER THE ATTENUATED OR REFERENCE POWER LEVEL CONFIGURATION		
MAN VS 7KW 613 ANTENNA	4.5	2.1
MAN VS 7KW 613T ANTENNA	----	2.1
H6 VS MAN	2.3	4.2
M6 VS MAN	4.5	8.3
L6 VS MAN	6.8	14.6
HT VS MAN	0.0	10.4
MT VS MAN	6.8	14.6
LT VS MAN	6.8	16.7
f. PERCENTAGE OF NON-RECIPROCAL FAILURES TO FIND AN M3000 FACTOR (of A/B MEASUREMENT, CONFIGURATION A FAILED B DID NOT)		
MAN/H6	2.2	14.6
H6/MAN	0.0	2.1
MAN/M6	0.0	10.4
M6/MAN	4.6	4.1
MAN/L6	0.0	4.2
L6/MAN	9.1	6.2
MAN/HT	4.5	6.3
HT/MAN	2.3	6.3
MAN/MT	0.0	2.1
MT/MAN	6.9	2.1
MAN/LT	0.0	4.2
LT/MAN	4.6	14.6

* This is the maximum percentage of the ionograms which could be correctly scaled manually or automatically. It was limited by a blaketing Es layer which blocked F region echos.

** The ARTIST often interpreted the multiple hop Es as an F trace. These errors were independent of transmitter power. Therefore to provide a clearer assessment of low power operation, the data records were edited to indicate that the ARTIST was "unable to scale" these ionograms.

WALLOPS IS. LOW POWER TEST - 1986

Figure 1 - OUTPUT POWER DURING TESTS



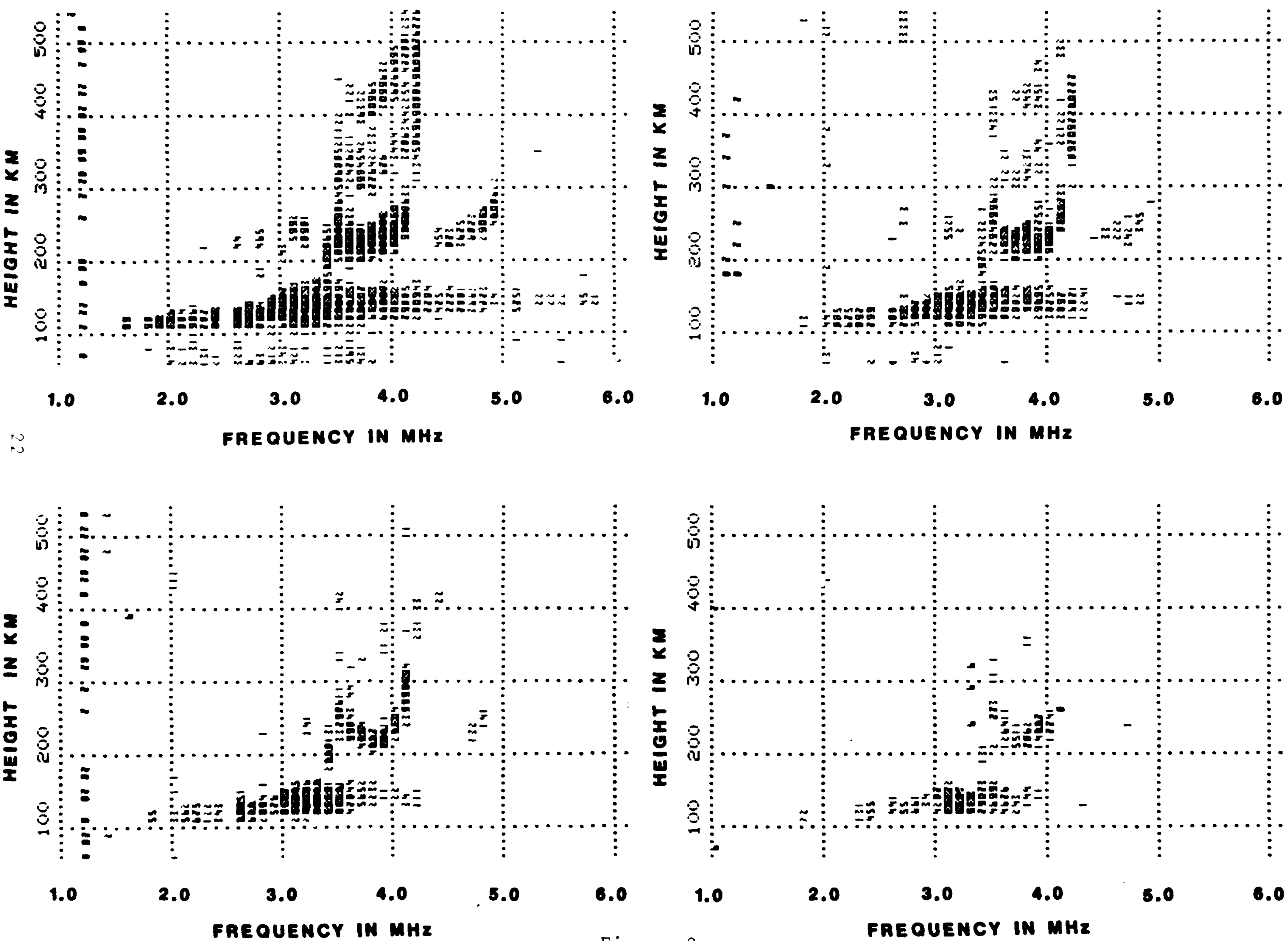
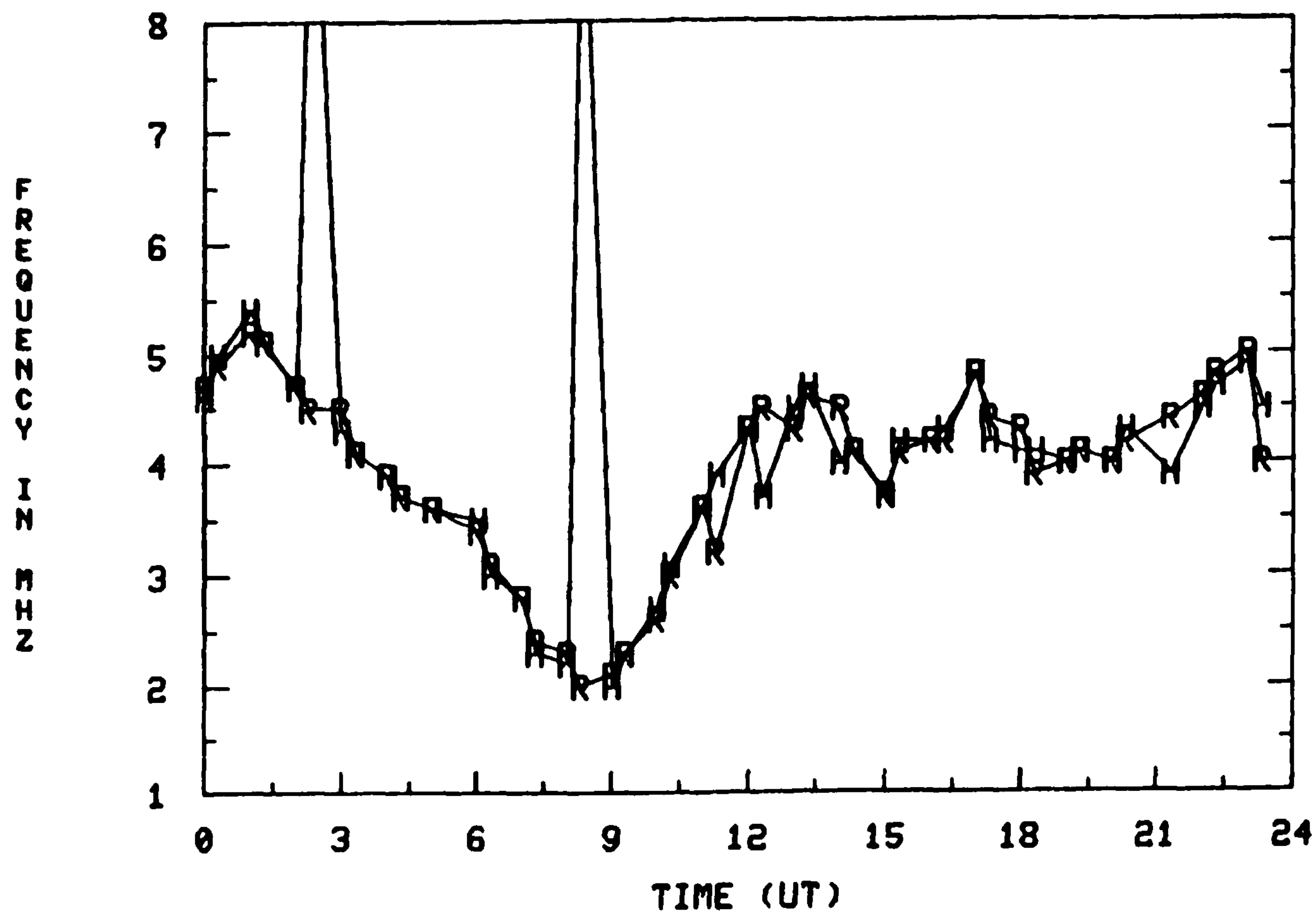

HEIGHT IN KM
100
200
300
400
500
1.0
2.0
3.0
4.0
5.0
6.0
FREQUENCY IN MHz

Figure 2

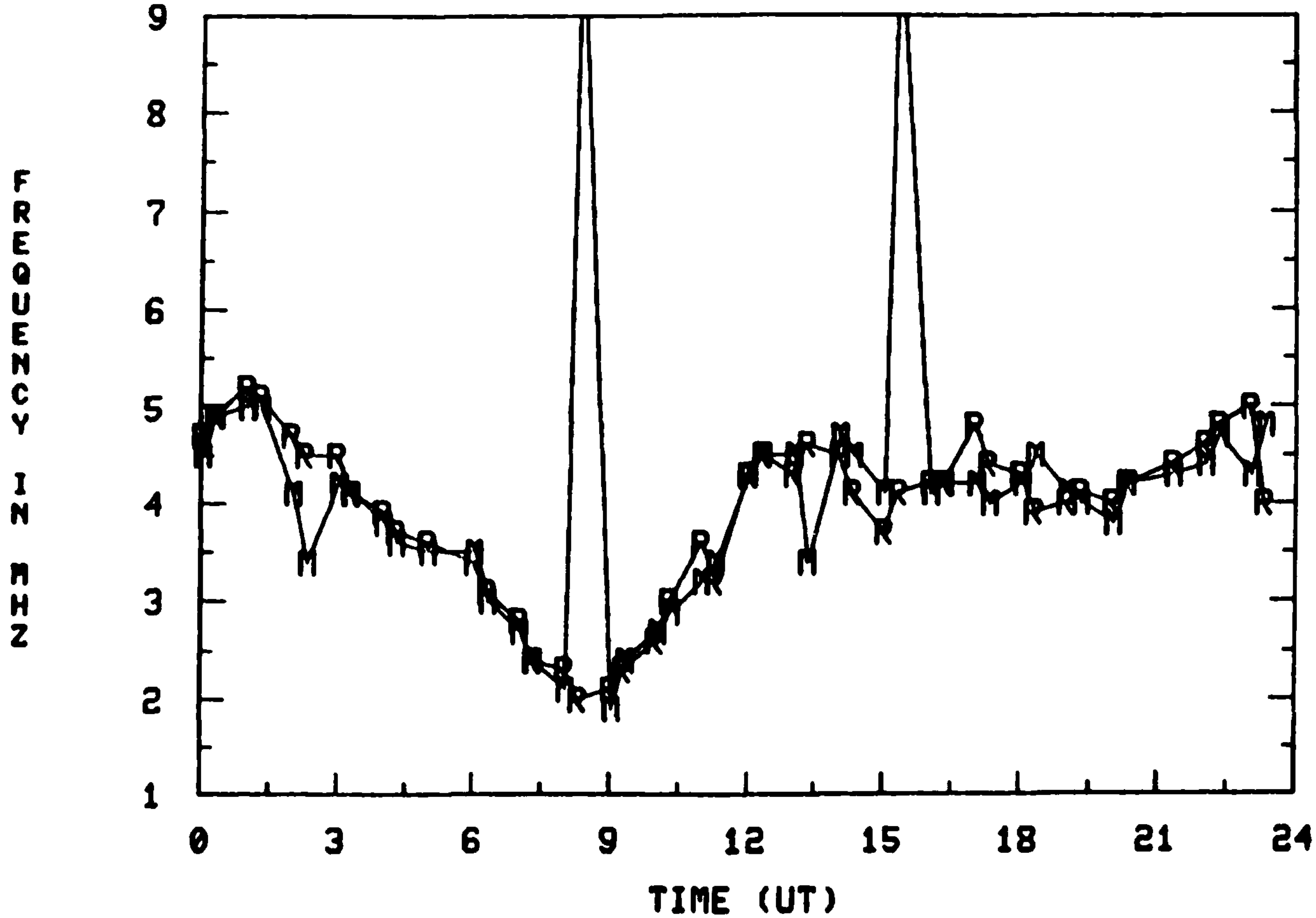
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 2A - FOF2'S FOR REF VS 1KW - 613 - DAY 176



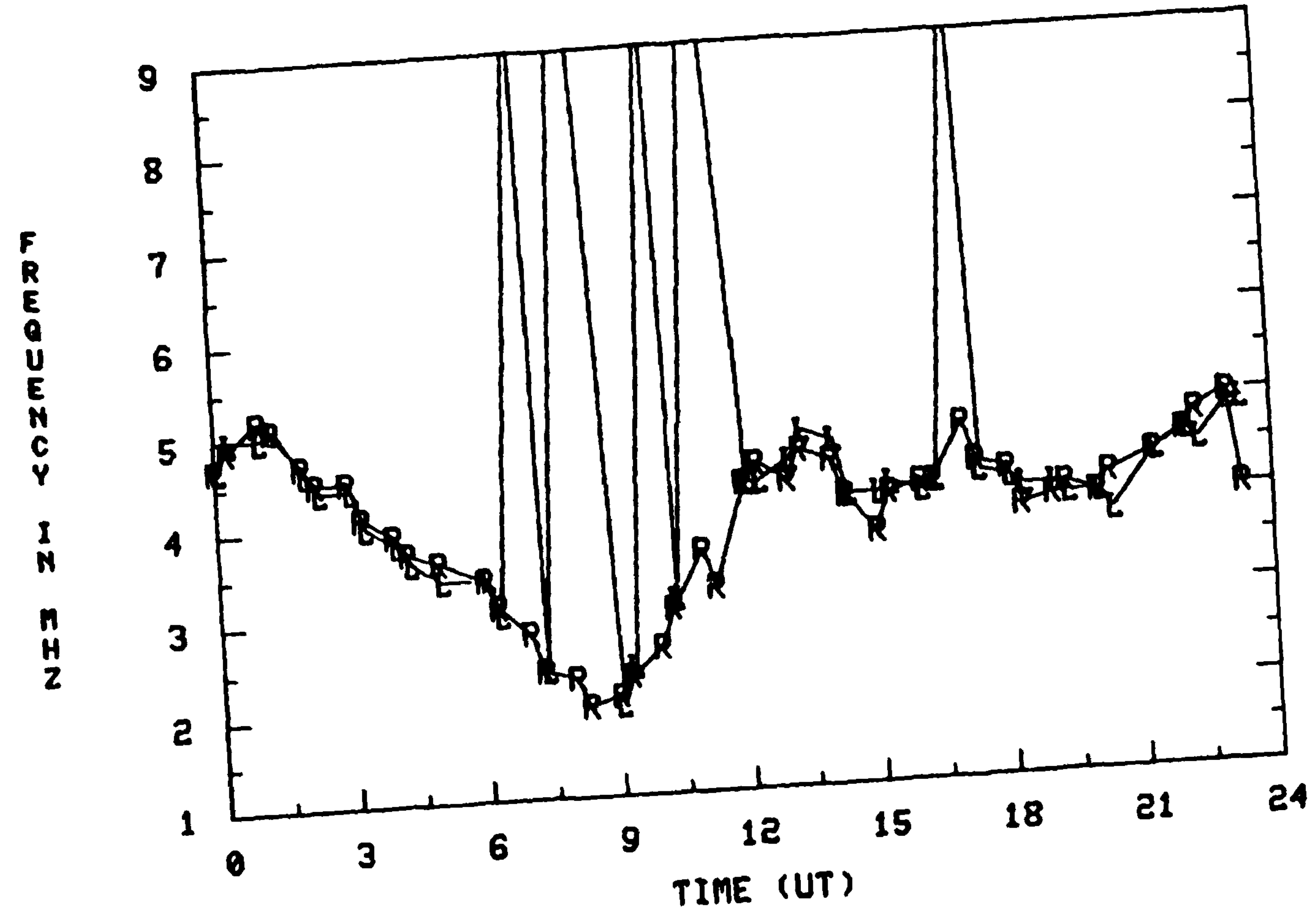
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 2B - FOF2'S FOR REF VS 170W - 613 - DAY 176



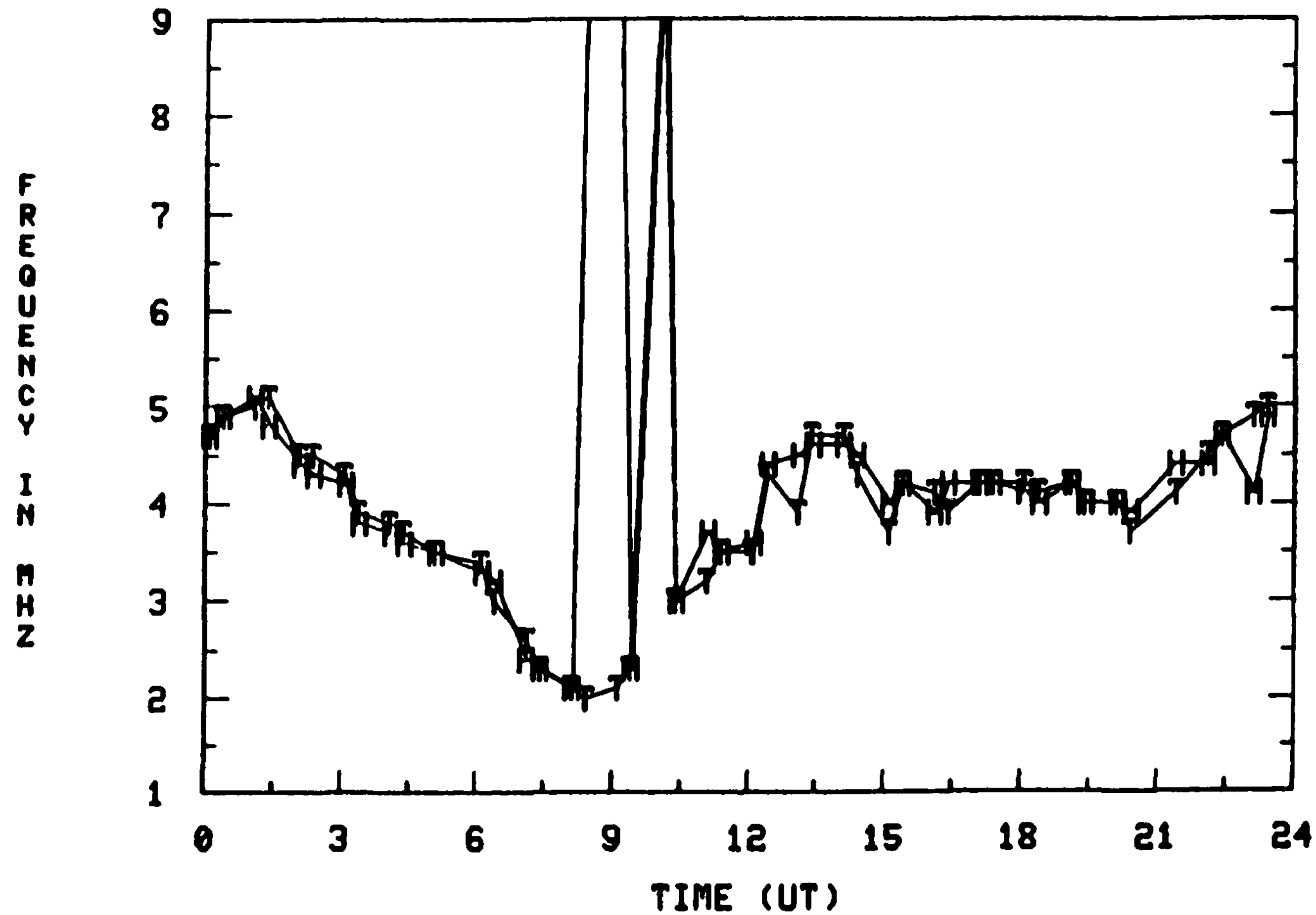
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 2C - FOF2'S FOR REF VS 30W - 613 - DAY 176



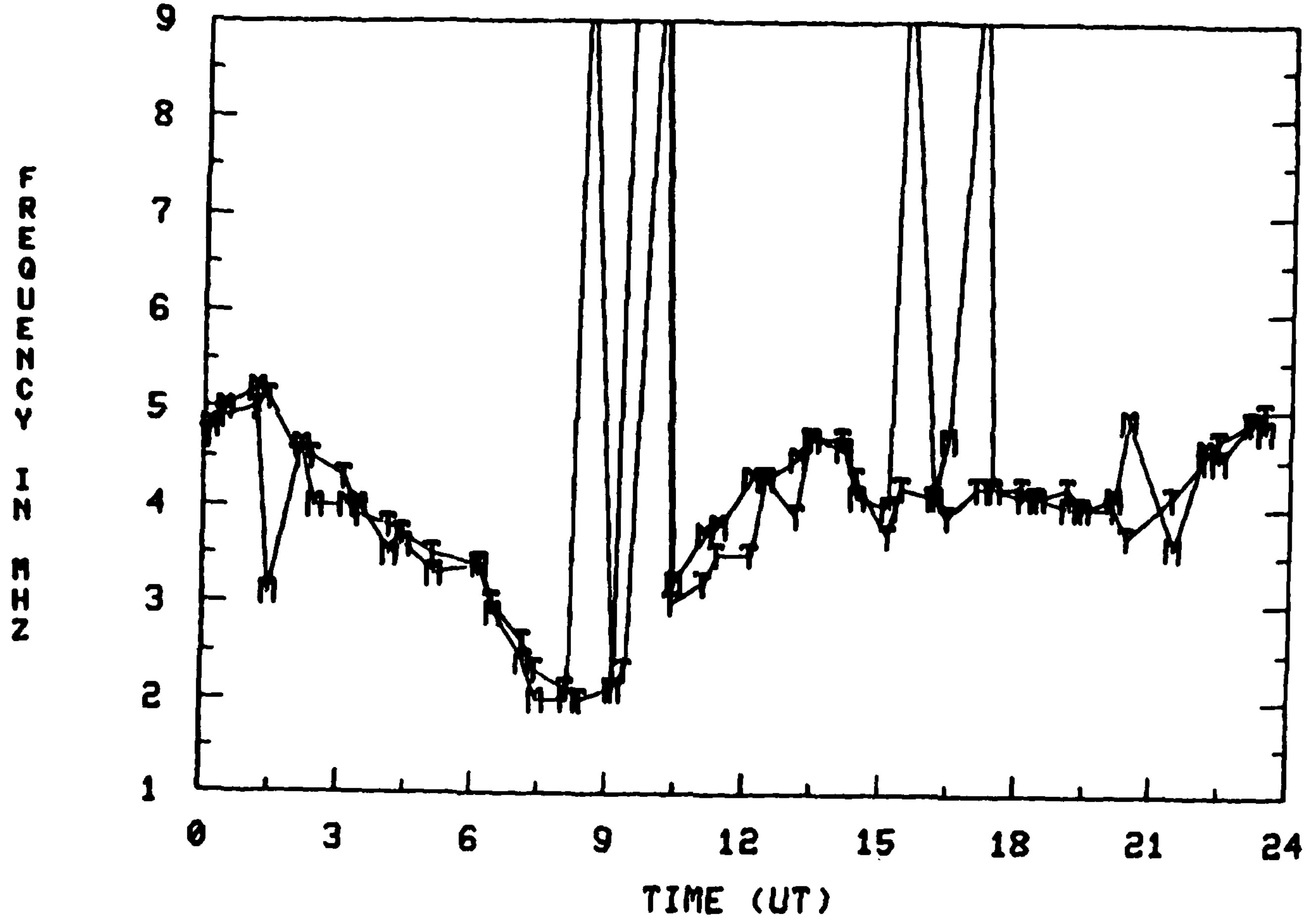
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 2D - FOF2'S FOR REF VS 1KW - 613T - DAY 176



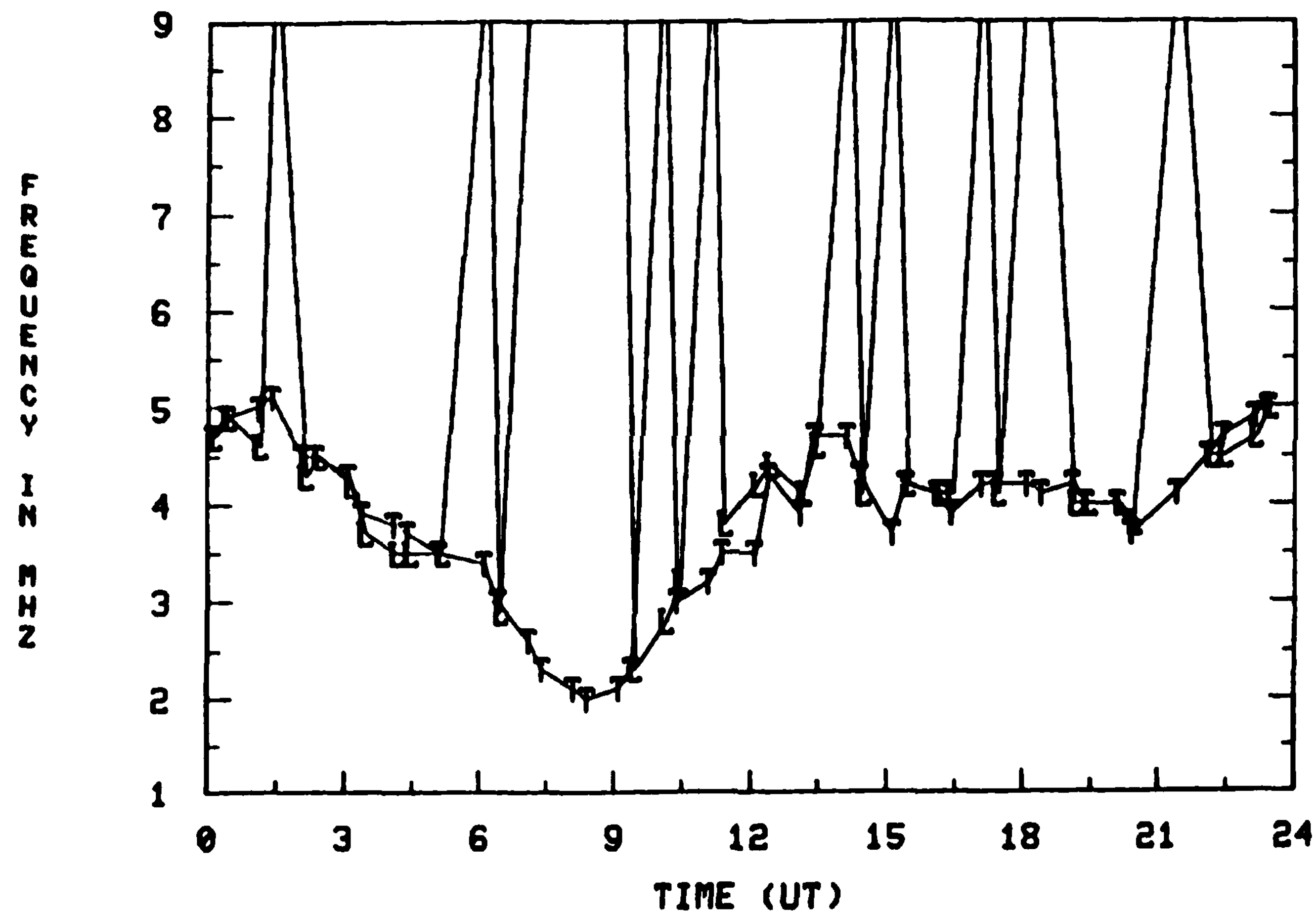
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 2E - FOF2'S FOR REF VS 170W - 613T - DAY 176



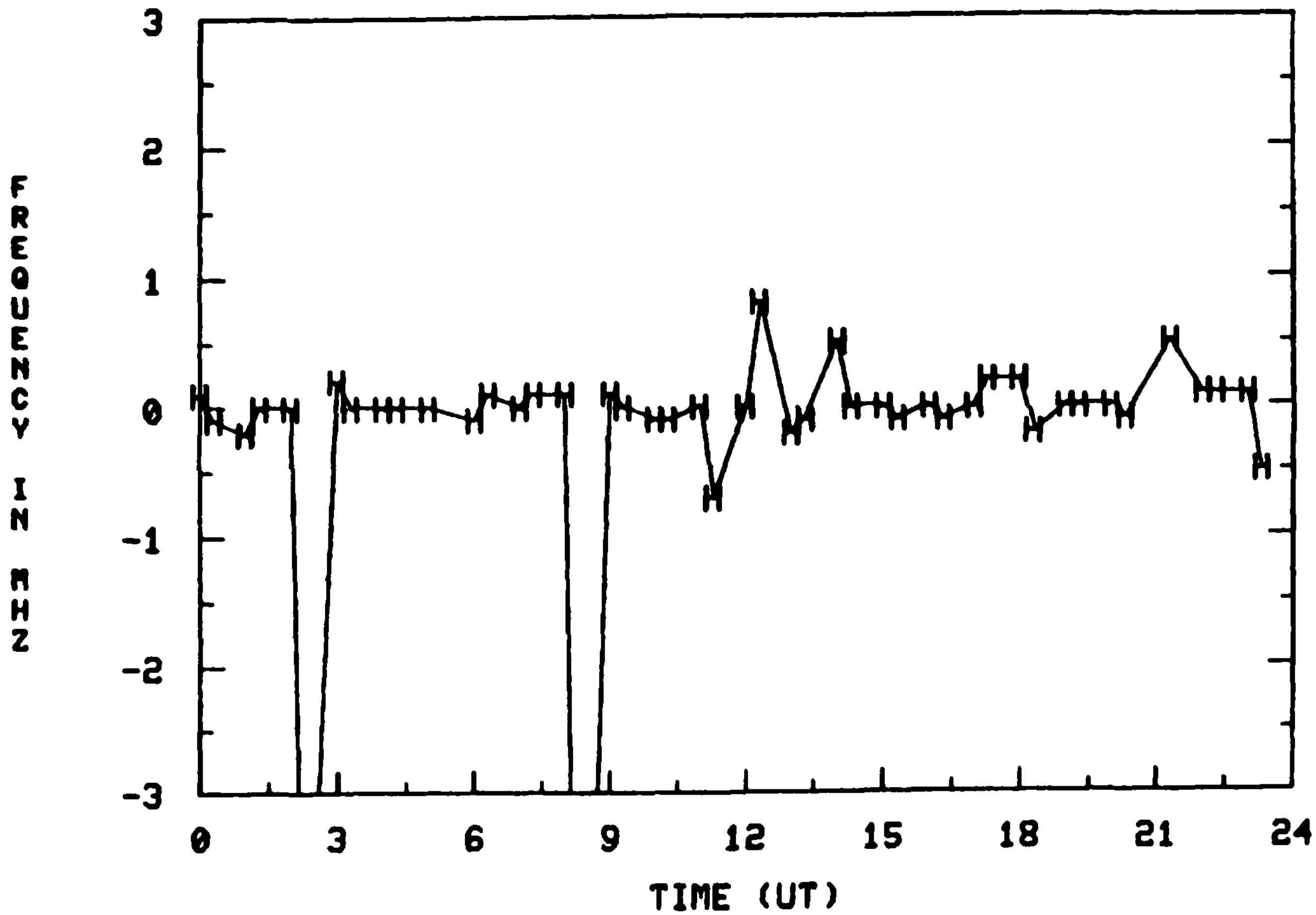
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 2F - FOF2'S FOR REF VS 30W - 613T - DAY 176



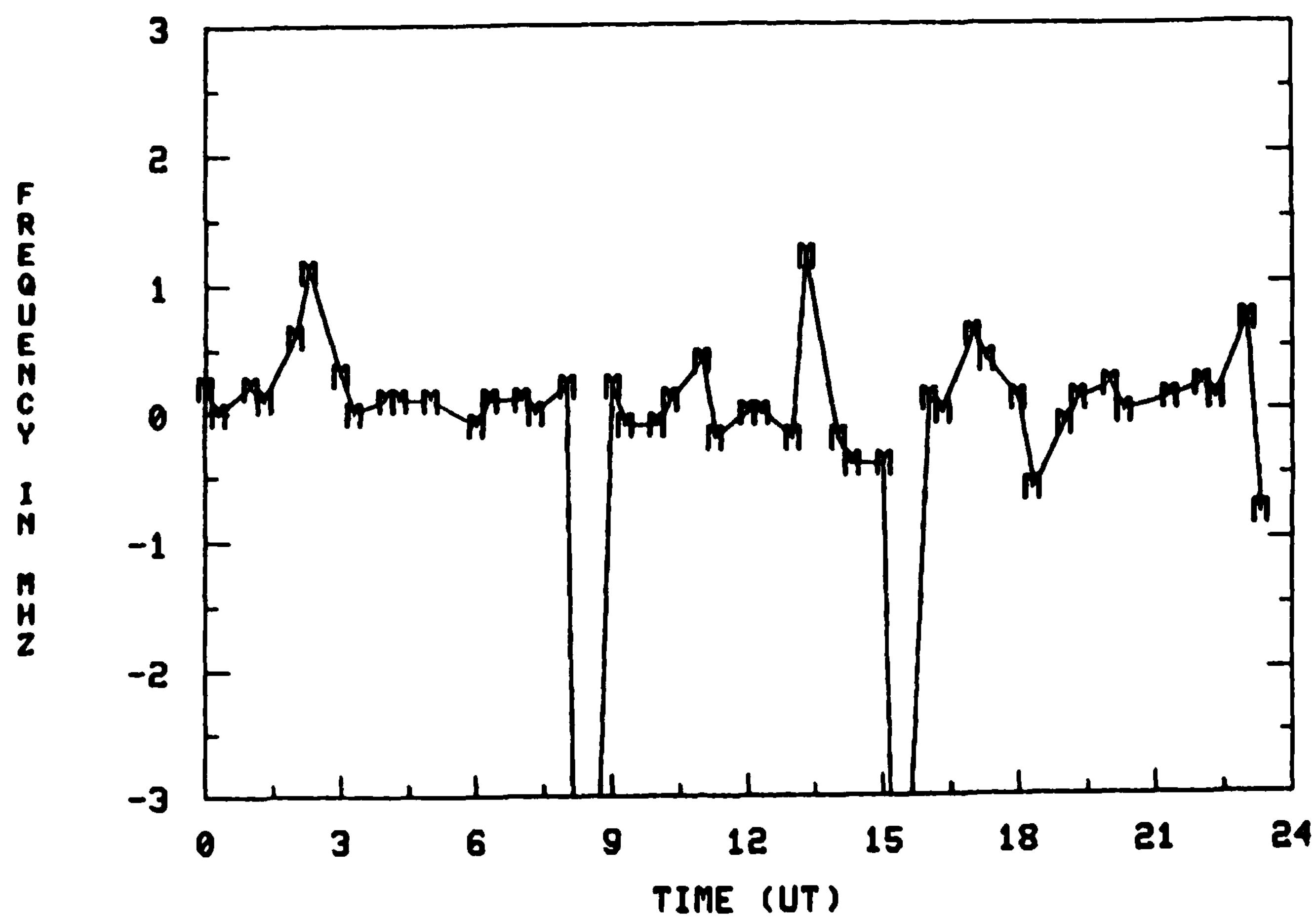
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 3A - DIFFERENCE IN REF AND 1KW FOF2'S - 613 - DAY 176



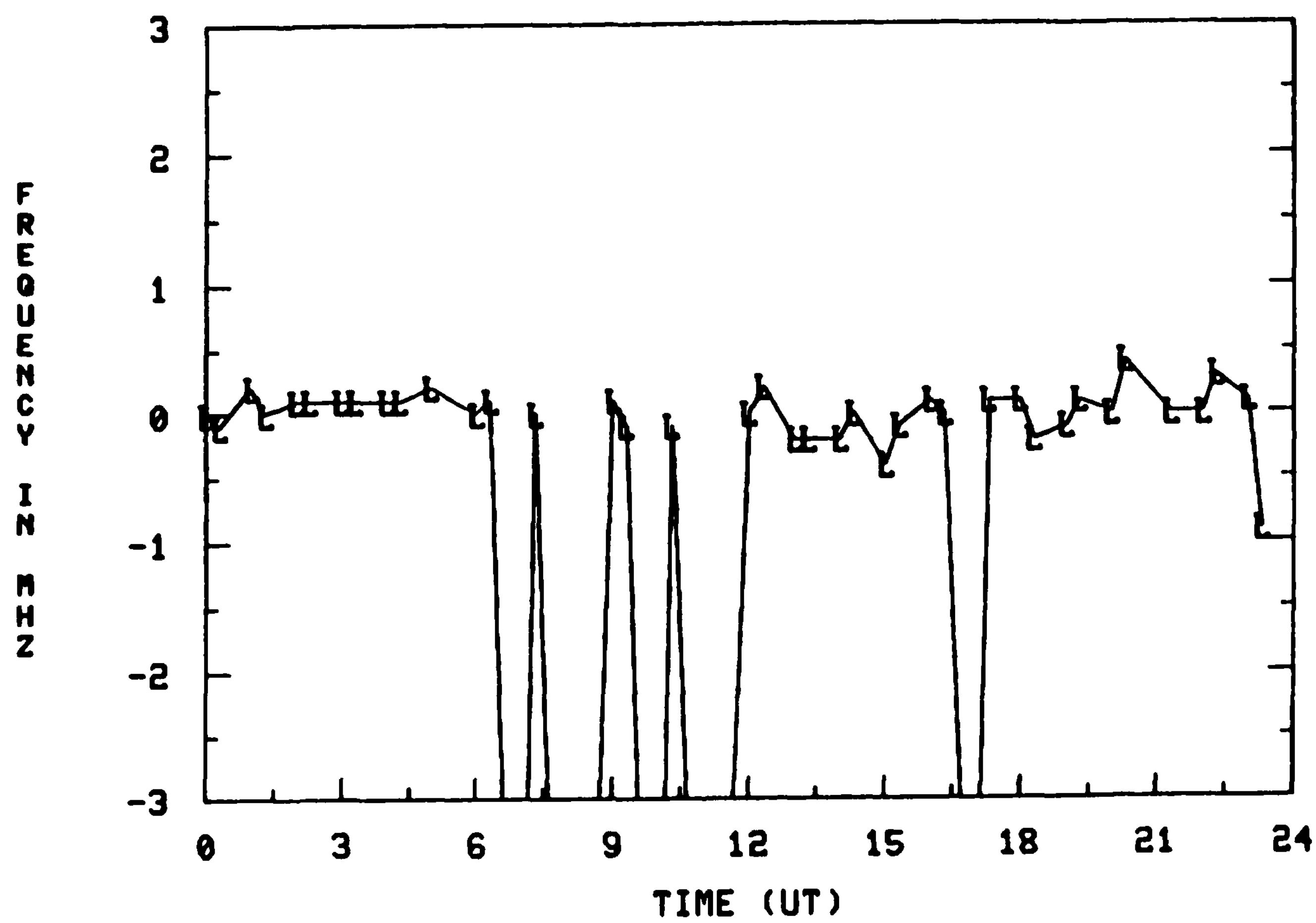
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 3B - DIFFERENCE IN REF AND 170W FOF2'S - 613 - DAY 176



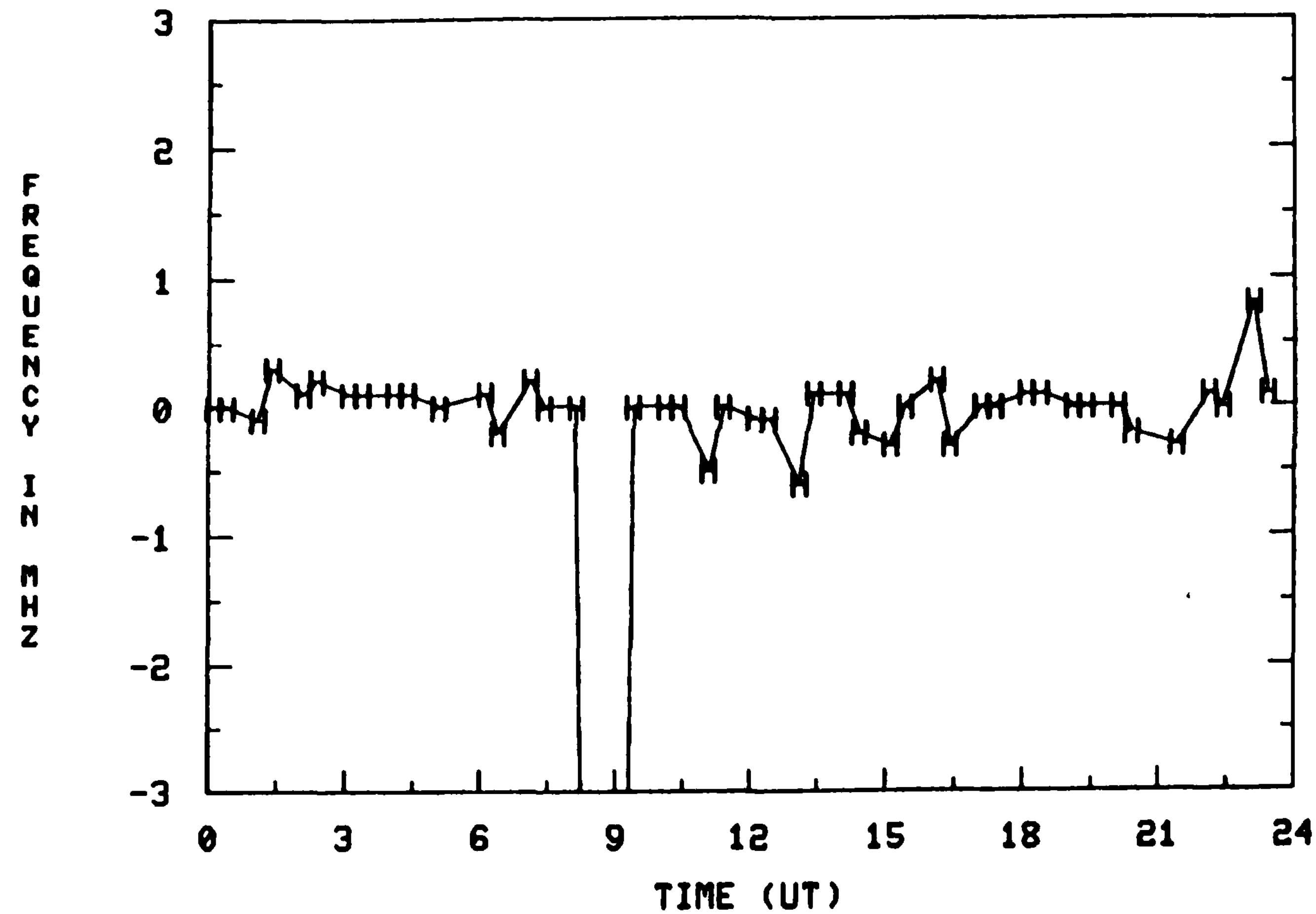
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 3C - DIFFERENCE IN REF AND 30W FOF2'S - 613 - DAY 176



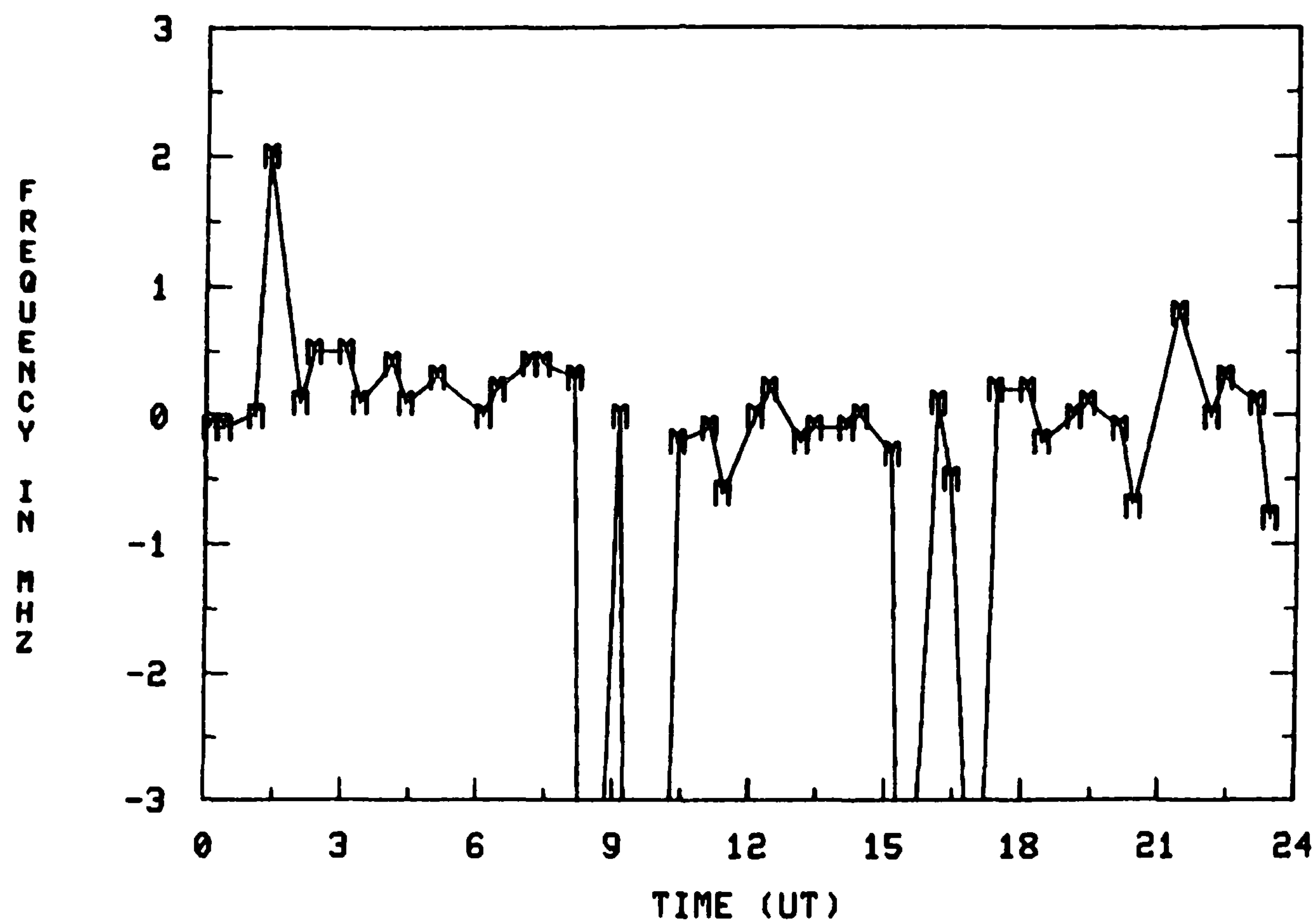
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 3D - DIFFERENCE IN REF AND 1KW FOF2'S - 613T - DAY 176



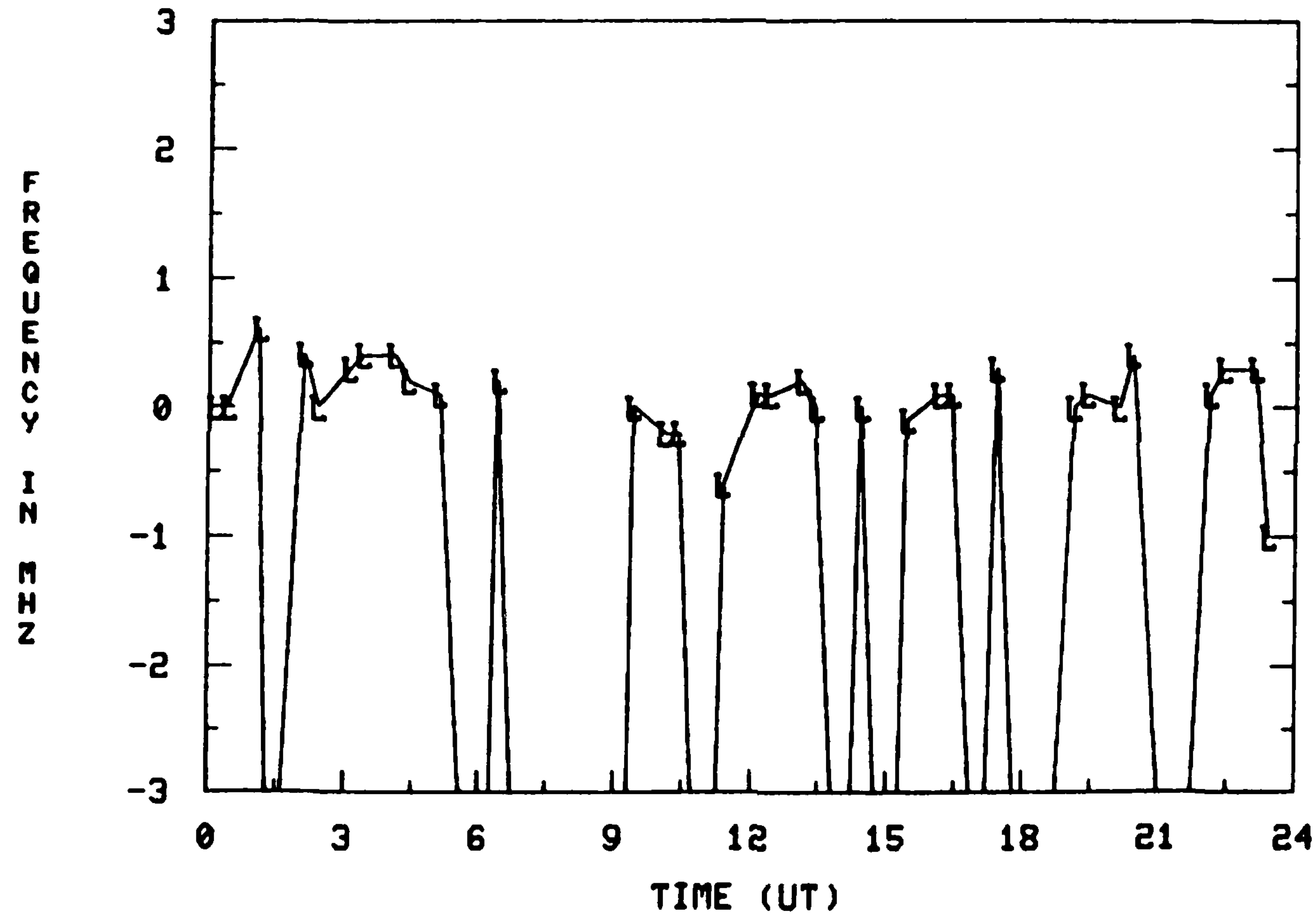
WALLOPS IS. LOW POWER TEST - 1986

FIGURE 3E - DIFFERENCE IN REF AND 170W FOF2'S - 613T - DAY 176



WALLOPS IS. LOW POWER TEST - 1986

FIGURE 3F - DIFFERENCE IN REF AND 30W FOF2'S - 613T - DAY 176



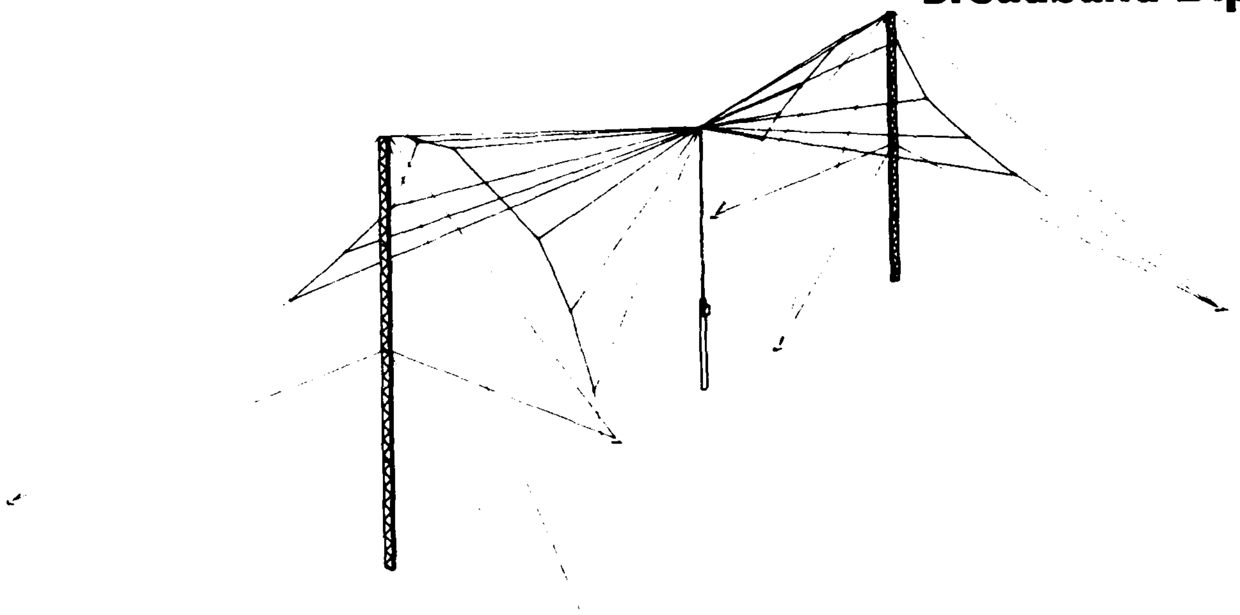
APPENDIX A

TCI Antenna Data

TECHNOLOGY FOR COMMUNICATIONS INTERNATIONAL **TCI**

MODEL **613**

Broadband Dipole



The TCI Model 613 is a truly broadband dipole antenna which provides excellent performance over short, medium, and long range circuits. The height and configuration of the antenna were chosen to provide high take-off angle radiation at the low frequencies optimum for short range communication and low take-off angle radiation at the higher frequencies necessary for longer range communications. At the take-off angles supporting short and medium range circuits, the azimuth pattern is essentially omnidirectional. This provides great flexibility and makes the 613 applicable to most communications requirements.

Broadbanding is achieved without the use of resistors or tuning units resulting in full antenna efficiency. Expensive transmitter power is radiated instead of being lost in tuning devices.

Operation is simplified because there is no need to tune the antenna.

Installation is simple. The two towers are short and lightweight. They may be completely assembled on the ground and easily erected as one unit with a gin pole and small hand winch. Moreover, because the towers are vertical (a very important consideration during erection), they may be safely guyed prior to curtain installation. Once erected, the curtain may be lowered at any time independent of the tower guying. Consequently, use of short vertical towers is critical in the safe and expeditious installation as well as in the ease of future maintenance.

The 613 shares with all TCI antennas the same high quality, exhaustively tested components and materials. All radiators, feedlines, and catenaries are of Alumoweld, a wire composed of a high strength steel core and a highly conductive corrosion resistant welded coating of aluminum.

Fixed station antennas traditionally have used fiberglass catenary and drop rod assemblies on the basis of its excellent dielectric and tensile strength properties. However, field experience has shown that minute, difficult-to-detect flaws in the material, RF burning, and small nicks incurred during installation handling may result in catastrophic structural failure later on, and deterioration when stored for long periods at high temperature and humidity. TCI antennas use Alumoweld catenaries, segmented by fail-safe insulators, an improvement which bypasses the poor structural properties of fiberglass.

- **Reliable Communications — Small Land Area**
- **Broadband (2-26 MHz) — No Tuning**
- **High Efficiency**
- **Easy to Install**
- **Supports Short, Medium, and Long Range Communications**

SPECIFICATIONS - MODEL 613

Polarization	**Horizontal**
Impedance	**50 ohms nominal**
VSWR	**2.0:1 or less over most of frequency band**
	2.5:1 maximum
Environmental Performance	**Designed in accordance with EIA Specification RS-222C for loading of 160 km/h (100 mi/h) wind**
	Optional: 225 km/h (140 mi/h) wind

Size

Model Number	Frequency Range	Height (ft)	Height (mtr)	Length* (ft)	Length* (mtr)	Width* (ft)	Width* (mtr)
613-1-N	**2-26 MHz**	**85**	**25.9**	**249.3**	**76.0**	**150**	**45.7**
613-2-N	**2.3-26 MHz**	**71**	**21.6**	**216.3**	**65.9**	**125**	**38.1**
613-3-N	**3.4-26 MHz**	**44**	**13.4**	**146.6**	**44.7**	**88.3**	**26.9**
613-3A-N	**6-26 MHz**	**25**	**7.6**	**87.8**	**26.8**	**50**	**15.2**
613-4-N	**4.3-26 MHz**	**35**	**10.7**	**116**	**35.4**	**69.8**	**21.3**

*Measured from extreme guy points

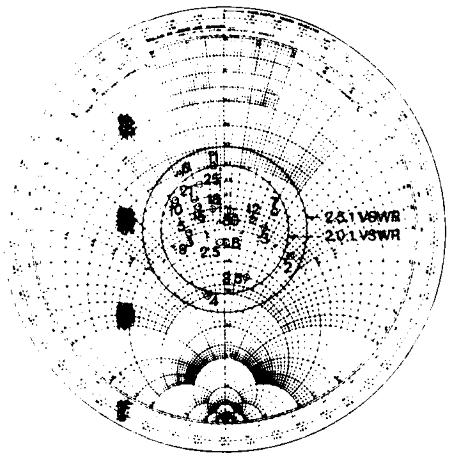
Shipping Weight and Volume

Model Number	Estimated Weight Pounds	Estimated Weight Kilograms	Estimated Volume Cubic Feet	Estimated Volume Cubic Meters
613-1-N	**2450**	**1110**	**86**	**2.44**
613-2-N	**2200**	**1000**	**80**	**2.27**
613-3-N	**1600**	**725**	**68**	**1.93**
613-3A-N	**900**	**410**	**54**	**1.53**
613-4-N	**1250**	**570**	**63**	**1.78**

Power

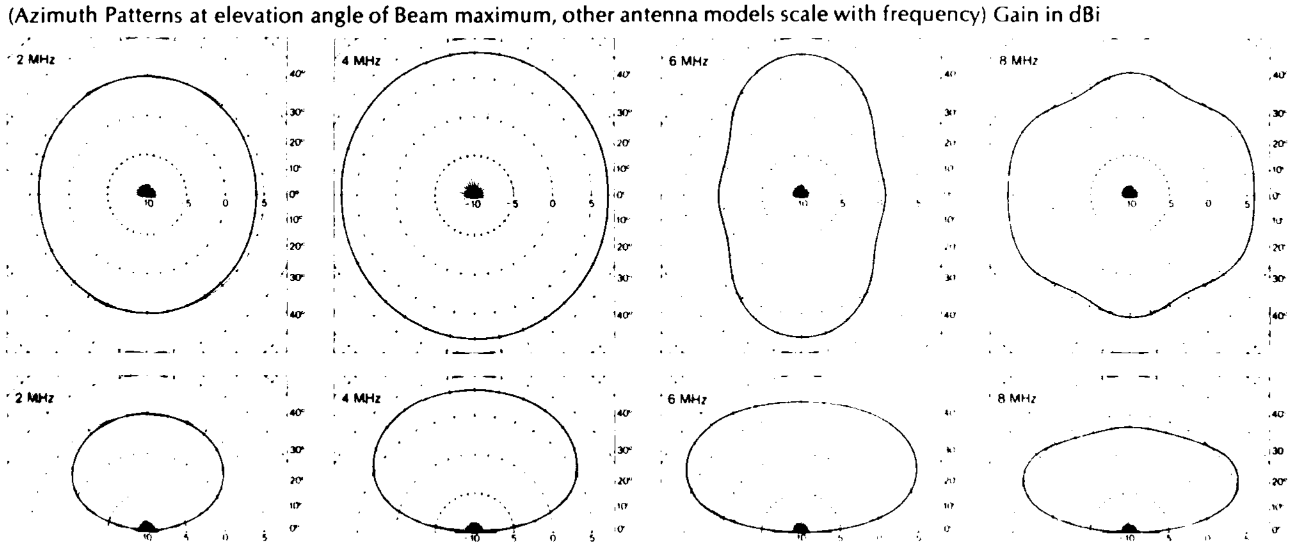
Model Number	Power Average	Power PEP	Connector
613-N-02	**Receive**	**Receive**	**Type N Female**
613-N-06	**1 kW**	**2 kW**	**Type N Female**
613-N-28	**5 kW**	**10 kW**	**⅞" EIA Female**
613-N-03	**10 kW**	**20 kW**	**1⅝" EIA Female**
613-N-09	**20 kW**	**40 kW**	**1⅝" EIA Female**

TCI 613-1 IMPEDANCE DATA



ELEVATION AND AZIMUTH PATTERNS for 613-1

(Azimuth Patterns at elevation angle of Beam maximum, other antenna models scale with frequency) Gain in dBi



TECHNOLOGY FOR COMMUNICATIONS INTERNATIONAL **TCI**

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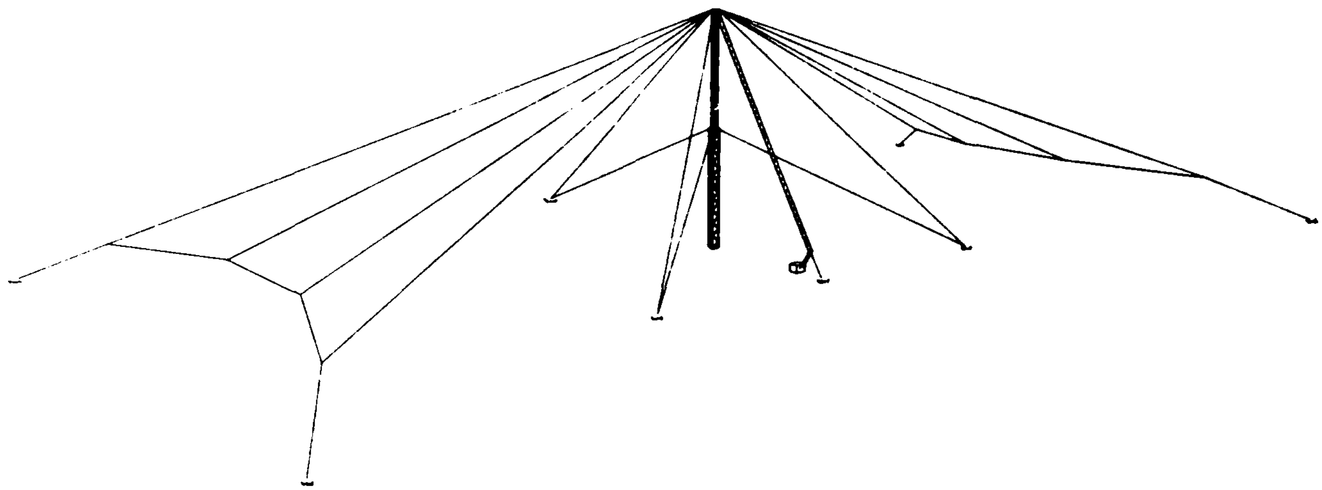
TECHNOLOGY FOR COMMUNICATIONS INTERNATIONAL **TCI**

MODELS **613 T AND F**

Broadband Dipole Antennas



The communications quality of quickly erectable, HF systems is commonly inhibited by poor antenna performance. The TCI Model 613T broadband dipole provides better electrical performance than narrow band dipoles or whips yet it is fast to erect, simple to transport, and requires no tuner.

The antenna is extremely lightweight for ease of conveyance, yet it is rugged enough to withstand the rigors of transport and installation. It is simple in design and mostly preassembled to allow rapid deployment, yet it packs easily and performs reliably. The antenna packs into a small, easily transportable container, yet the erected structure has a large radiating aperture. It provides high gain, smooth radiation patterns, and nearly constant impedance. It outperforms ordinary dipoles because it is truly wideband and has no deep azimuth nulls. It outperforms whips because it provides good high-angle gain for short range communication and it requires no troublesome tuner.

The Model 613T is a single tower quickly erectable, wideband dipole antenna. It is ideal for short and medium range tactical military communications where a high degree of transportability is required. It will perform its mission over a wide range of ground and terrain conditions. In operation, the Model 613T is less visible than those with taller towers, a valuable asset in tactical environments. Because of its compact design, this antenna is more rugged and reliable than other high-performance transportable antennas.

The tower is assembled on the ground from 10 foot (3.05 meter) sections and is tilted upright. The hinged base and side guys assure stability throughout the erection procedure. No winch or derrick is required. The antenna is supplied complete with welded aluminum tower, curtain, ground return wire, resistive terminations, guys, screw-in anchors, balun, all tools required for installation, and the rugged aluminum boxes in which the antenna is transported.

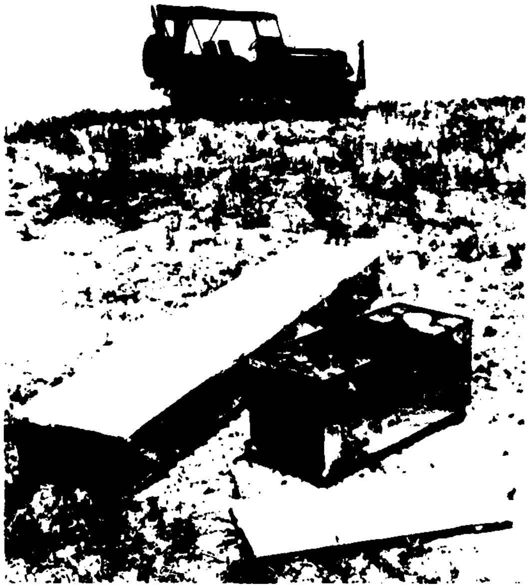
Curtain, catenary, and ground screen wires are phosphor-bronze for flexibility and ease of handling. They can be coiled and uncoiled repeatedly without damage. Tower guys are made of tough polypropylene rope. The resistive terminations are mounted in protective, ventilated containers.

The Model 613F is electrically identical to the 613T but is intended for fixed station use. Its curtains, catenaries, and guys are made of Alumoweld wire and the tower is galvanized steel. Guys and catenaries are segmented by insulators where appropriate. The anchors and tower base are set in concrete. No installation tools or reusable boxes are supplied with the 613F.

- **Quickly erectable**
- **Highly transportable**
- **2-30 MHz— No tuner required**
- **Omnidirectional**

SPECIFICATIONS

Polarization		**Horizontal**
Impedance		**50 ohms nominal**
VSWR		**2.0:1 nominal** **2.5:1 maximum**
Environmental Performance	613T	**Designed in accordance with EIA Specification RS-222C for loading of 160 km/h (100 mi/h) wind, no ice** **40 km/h (25 mi/h) wind during erection**
	613F	**225 km/h (140 mi/h) wind, no ice** **145 km/h (90 mi/h) wind, 12 mm (½") ice**
Erection Time	613T	**1 hour by 2 men (excluding guy anchors)**



Power

Model Numbers Transportable	Fixed	Power Average	PEP	Connector
613T-1-02	**613F-1-02**	**Receive**	**Receive**	**Type N Female**
613T-1-06	**613F-1-06**	**1 kW**	**2 kW**	**Type N Female**
613T-1-28	**613F-1-28**	**5 kW**	**10 kW**	**1⅝" EIA Female**

Size

Model Numbers Transportable	Fixed	Frequency Range	Height (ft.)	(m)	Length (ft.)	(m)	Width (ft.)	(m)
613T-1-N	**613F-1-N**	**2-30MHz**	**40**	**12.2**	**220**	**67.1**	**56**	**17**

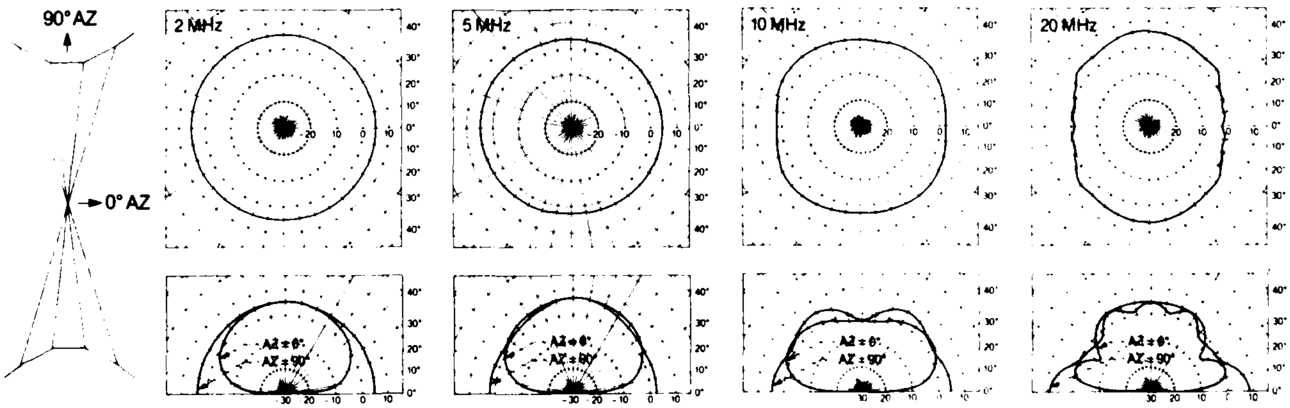
Antenna Efficiency

Frequency (MHz)	Efficiency (dB)
2	**−12.7**
3	**− 8.8**
5	**− 6.4**
7.5	**− 4.8**
10	**− 4.2**
20	**− 2.8**
30	**− 2.1**

Dimensions when packed for transit

Model Number	Weight (lbs)	(kg)	Volume (cu. ft.)	(cu. m)	Maximum dimension of largest case (ft.)	(m)
613T-1-06	**360**	**164**	**34**	**0.95**	**10**	**3.07**

ELEVATION AND AZIMUTH PATTERNS (Directive gain in dBi over perfect ground. Azimuth orientation as shown. Azimuth patterns at elevation of beam maximum.)



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